

INTRODUCTION

The intended purpose of this book is to give a safe set of AC ratings for TRW Polyester-Foil Capacitors. The ratings established here are the results of extensive testing in the TRW Capacitor R&D and Environmental Laboratories and can be used as a reliable reference.

The first section defines a listing of terms that are involved in the corona phenomena. The following two sections establish basic properties of the corona phenomena and the effects of voltage, temperature and frequency on the corona voltages. Then the effects of AC-DC voltages are discussed in light of the absence of corona.

The final section deals with the actual ratings and necessary rules for applying them.

TRW Capacitors Military and Industrial Engineering Department will be most happy to assist you in any applications involving AC-DC conditions and answer any questions you may have regarding this text.

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DEFINITIONS

Corona:

Any electrically **detectable**, field intensified ionization that does not result immediately in complete breakdown of the insulation and electrode system in which it occurs. (The American Society for Testing Methods.)

Corona Pulse:

The observed response to a single corona discharge.

Continuous Corona:

The observed corona pulses which occur approximately once each cycle of applied voltage.

Corona Onset Voltage:

The lowest A.C. rms voltage at which corona occurs as the voltage is increased from zero.

Corona Offset Voltage:

The A. C. rms voltage at which corona pulses no longer occur as the voltage is decreased from above the corona onset voltage.

CORONA

Corona, as defined above, encompasses many cause and effect situations. Although the effects may not take place immediately, it is well to understand the corona phenomena, and the causes behind it.

The questions that come to mind are:

1. How and where does ionization take place in a capacitor?
2. Why does not the insulation breakdown?
3. What effect does ionization have on the insulation?

In order to answer these questions it is necessary that one have some understanding of electrostatic field theory. We will not attempt to cover this subject here, but one important result from electrostatic field theory in which we are interested is:

The electric field gradient (volts/mil) in air perpendicular to a dielectric will be greater than the electric field gradient in the dielectric by the relative dielectric constant unless there is a surface charge on the dielectric.

This rule comes from the law that electric flux can only emanate or terminate on an electric charge.

As an example of the above rule, assume the electrode and insulation arrangement shown in Figure I with an insulation whose relative dielectric constant is 3. Also assume that the electric field gradient in the insulation is 1000 volts per mil, a value below the electric breakdown of the insulation.

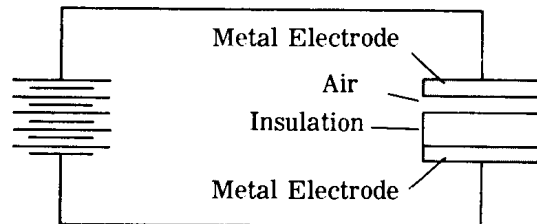


Figure 1

According to the results stated above, the electric field gradient in air between the top electrode and the insulation will be 3×1000 volts-mil or 3000 volts-mil, a value well above the electric breakdown of air.

The insulation is stressed well below its electric breakdown while the air is stressed well above its breakdown. The air breaks down or ionizes and a transfer of charge between the metal electrodes and the upper surface of the insulation occurs. In practice the electric field gradient in air will never reach 3000 volts-mil

since the air will breakdown when the breakdown potential for air is reached.

In this example, the transfer of charge continues until enough charge is deposited on the surface of the insulation so that most of the electric flux in the insulation will emanate from the surface charge rather than from the top electrode. There will be very little voltage drop across the air gap.

Reversing the polarity of the battery in Figure 1 will result in a repetition of the action described except the charge will be in the opposite direction.

The transfer of charge is very similar to minute arcing and thus, can damage the insulation. Like arcing it can be detected by visual, aural, or electrical means. Each of the following factors contribute to the actual damage to the insulation:

1. Bombardment of the dielectric by electrons.
2. Bombardment of the dielectric by positive ions.
3. Charring of the dielectric surface by the heat produced by the arc.
4. Chemical reaction caused by new compounds such as ozone produced by arc like conditions.

Most capacitors have small air voids between the plate and the dielectric in which corona can occur. Air voids are most likely found at the edge of the plate where it terminates between the insulations (where the safety margin is formed). When corona is present in a capacitor, it is usually found at this point.

Continuous corona occurs when sinusoidal waves or recurrent transients are applied which are above the corona onset voltage regardless of the amount of D.C. voltage component of the applied voltage. Corona cannot be continuous under D. C. conditions unless several thousand volts are applied. Therefore, the continuous corona measurements are made using A. C.

voltages.

The corona offset voltage, rather than the corona onset voltage, should always be used as one of the criteria for establishing safe operating levels. The corona onset voltage will always be a value which is equal to or greater than corona offset voltage. The corona onset voltage is not predictable, and may be 2 or 3 times the value of the corona offset voltage. Also, corona onset voltage will sometimes approximately equal the offset value once corona has occurred even though the initial onset value was 2 or 3 times the offset value.

CORONA VS DC VOLTAGE RATING

Corona offset voltage will vary as the DC voltage rating varies. However, when holding temperature and frequency constant for a specified DC rating, the corona offset voltage will always be within a narrow band of values. The curve of Figure 2 is the result of testing various DC ratings of Mylar. Figure 3 is another curve of corona offset voltage versus Polyester thickness, but showing safe maximum values.

The data for producing the curve of Figure 2 is compiled in Table I below.

VOLTAGE RATING	CORONA OFFSET VOLTAGE	
	Ave.	Min.
100 VDC	279.6 vrms	270 vrms
200 VDC	293.0 vrms	285 vrms
400 VDC	337.0 vrms	320 vrms
600 VDC	342.0 vrms	335 vrms

Table I

**CORONA OFFSET VOLTAGE
VS
VDC RATING TEST RESULTS**

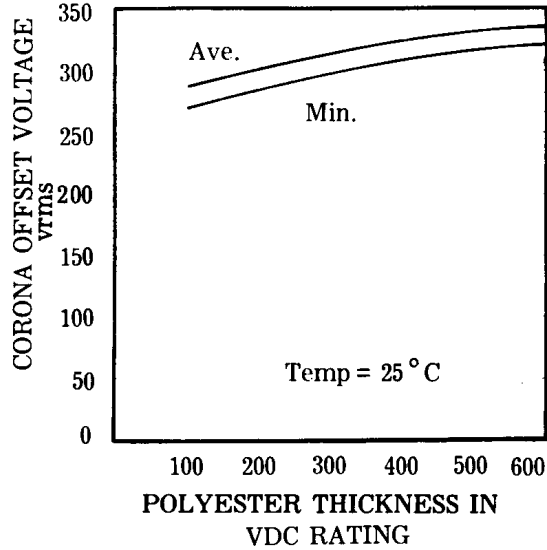


Figure 2

**CORONA OFFSET VOLTAGE
VS
VDC RATING
SAFE WORKING MAXIMUM**

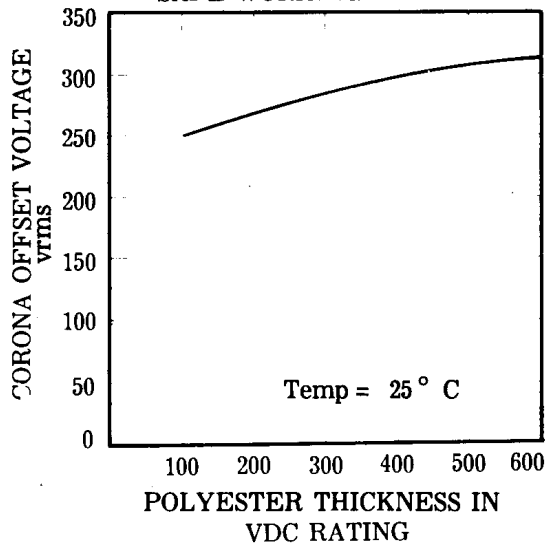


Figure 3

A study of Table I reveals that for any specified DC rating, the maximum difference between the average and minimum values of corona offset voltage was only 17 vrms.

The corona appears across the air gaps as was explained earlier in the discussion of the corona theory. It follows from this, that if the units are impregnated the corona offset voltage levels will be higher than those levels in the unimpregnated units. This is because the air gaps are filled with the impregnant which has a higher dielectric constant.

CORONA VS TEMPERATURE

The corona offset voltage for the particular unit is essentially not affected through the temperature range of room temperature to 125° C.

Figure 4 is a curve of corona offset voltage versus temperature based on test results. Figure 5 is a similar curve of the safe working values. The data for the curve in Figure 4 is compiled in Table II below.

TEMPERATURE	POLYESTER THICKNESS IN VDC RATING	
	600 VDC	200 VDC
31° C	343 vrms	295 vrms
50° C	340 vrms	294 vrms
85° C	337 vrms	294 vrms
125° C	338 vrms	291 vrms

TABLE II

The information in the curves and the table show that the change in the corona offset voltage is very slight, 6 volts for the 600 units and 4 volts for 200. When considering the effect of temperature, the safe working curve of corona offset voltage versus DC Voltage Rating in Figure 5 can be used as a reliable reference.

CORONA VS FREQUENCY

The corona offset voltage level for Polyester units drops slightly in the frequency range of 60 through 20,000 cps.

Test results for corona offset voltage versus frequency at room temperature are compiled in Table III.

VOLTAGE RATING	60 CPS	20,000 CPS
100 VDC	271 vrms	260 vrms
200 VDC	288 vrms	269 vrms
400 VDC	322 vrms	268 vrms
600 VDC	342 vrms	271 vrms

Table III

The results in Table III verify that corona offset voltage is slightly effected by a change in frequency. However, from these results, it appears that at 60 cps the corona offset voltage could be raised to some higher level merely by increasing Polyester thickness but at 20,000 cps the corona offset level remains essentially constant. This would lead one to believe that at a frequency of 20,000 cps Polyester thickness could be increased indefinitely with no increase in the corona offset voltage level.

CORONA OFFSET VOLTAGE VS TEMPERATURE TEST RESULTS

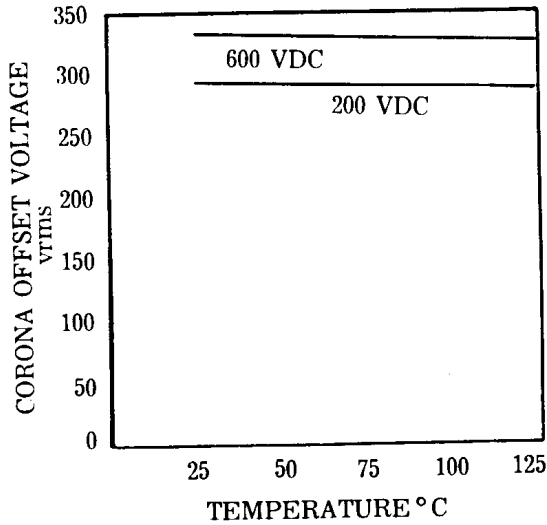


Figure 4

CORONA OFFSET VOLTAGE VS TEMPERATURE SAFE WORKING MAXIMUM

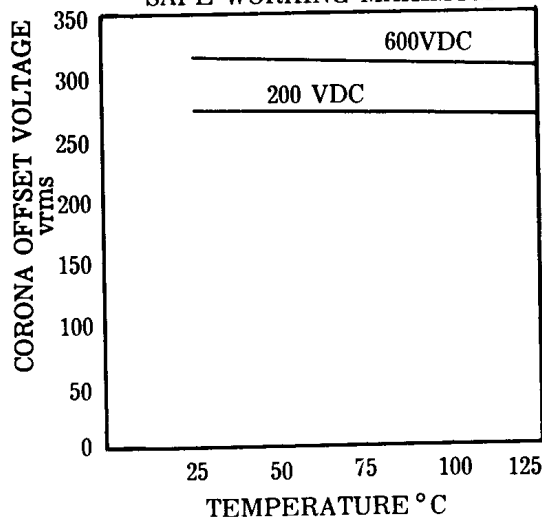


Figure 5

AC AND AC + DC EFFECTS ON CAPACITOR ELECTRICAL CHARACTERISTICS

The electrical characteristics of Polyester capacitors are not adversely affected by applying various combinations of voltages as long as corona is not present.

The results of tests with different voltage combinations are compiled in Table IV. The maximum average change in capacitance was only 1.55 pct. for a group of 200 VDC units operated at 500 VDC for 4644.2 hours.

In another test, 600 VDC units were tested for 6150.8 hours at 85 °C and with 750 VDC plus 212 vrms applied. As can be seen from Table IV, the change in capacitance was only 0.44, the IR after test was 1710K megohms and the % D.F. was 0.45.

FAILURES - None

TOTAL NUMBER UNITS TESTED-82

TOTAL NUMBER CAPACITOR HOURS-
296,152.4

FREQUENCY - 1000 CPS

No. Units	Cap.-Mfd WVDC	Temp. °C	Test Voltage	Test Hours	% D.F. (Ave.)		2 Min. I.R. (Ave. K Megohms)		Cap. Change %Ave.
					Before	After	Before	After	
10	.02-600	85	212 rms+750DC	6150.8	0.36	0.45	1670	1710	+0.44
12	.1 -200	85	500DC	4644.2	0.31	0.34	632	893	+1.55
12	.1 -200	85	65 rms+408DC	4644.2	0.31	0.34	630	854	+1.39
12	.1 -200	85	212 rms+200DC	4644.2	0.30	0.34	580	812	+1.28
12	.02-600	125	212 rms+750DC	1123.7	0.36	0.37	1867	1675	+1.30
12	.02-600	125	212 rms+400DC	1123.7	0.36	0.36	1850	1892	+1.27
12	.02-600	125	212 rms+100DC	1123.7	0.35	0.35	1808	1725	+0.95

Table IV

AC RATINGS

Polyester capacitors can be operated under AC conditions with complete confidence within specific voltage rating as long as two basic rules are observed:

1. The sum of the DC voltage and the AC rms voltage does not exceed the DC rating of the capacitor.
2. The AC component (rms) does not exceed the corona offset voltage.

Table V is a set of reliable AC ratings for TRW capacitors through a frequency of 1000 cps. These ratings, which are compared against DC ratings, are also shown graphically in Figure 6.

Rated rms Voltage (85° C)	Rated DC Voltage (85° C)
100	100
200	200
225	400
250	600
275	1000

Table V

The AC ratings are the results of bulk data as evidenced by the test results of Table VI. All of the tests recorded by Table VI were conducted at 125°C. Therefore, the AC ratings include an even greater safety factor when the capacitor is operated at lower temperatures.

The reliability of the ratings in Table V is further justified by the results of 1.0 mfd. that successfully withstood 1000 cps testing equal to or in excess of the AC or AC + DC ratings. One microfarad units rated at 400 VDC were tested at 250 vrms at 85°C without failure. Other 1.0 mfd units rated at 600 VDC were tested at 250 vrms plus 350 VDC at 85°C and also at 250 vrms + 50 vdc at 125°C without failure.

A comparison of the ratings of Table V with the safe working curves for corona offset voltages of Figures 3 and 5 show the Table V ratings to be more conservative. It is important to note that the corona offset voltage studies for various DC ratings and temperatures of Figures 3 and 5 did not involve any consideration as to life expectancy or overall performance.

TOTAL NUMBER UNITS TESTED - 396
 TOTAL CAPACITOR HOURS - 292,336.6

TEMPERATURE - 125 °C

VOLTAGE RANGE: 100 vrms - 275 vrms,
 200 vrms + 100 vdc, 250 vrms + 250 vdc

FREQUENCY: 1000 cps

Units	Cap - Mfd WVDC	Test Volts	Test Hours	No. Failures	Capacitor Hours
24	.1 - 100	100 rms	500.5	0	12,012.0
24	.1 - 100	100 rms	1875.0	0	45,000.0
24	.1 - 100	100 rms	525.0	0	12,600.0
24	.1 - 100	100 rms	500.0	0	12,000.0
12	.1 - 200	200 rms + 100 DC	525.5	0	6,306.0
12	.1 - 200	200 rms + 100 DC	1010.0	3	11,220.0
12	.1 - 200	200 rms + 100 DC	1149.8	0	13,797.6
12	.1 - 200	200 rms + 100 DC	500.5	0	6,006.0
24	.1 - 200	200 rms	500.0	0	12,000.0
24	.1 - 200	200 rms	501.5	0	12,024.0
24	.1 - 200	200 rms	1895.0	0	45,480.0
12	.1 - 400	250 rms + 250 DC	540.0	1	5,940.0
12	.1 - 400	250 rms	500.5	0	6,006.0
12	.1 - 400	250 rms	500.0	2	5,508.0
12	.1 - 400	250 rms	512.0	1	6,002.0
12	.1 - 400	225 rms	503.0	0	6,036.0
12	.1 - 400	225 rms	507.0	0	6,084.0
12	.1 - 400	225 rms	500.0	0	6,000.0
12	.1 - 400	225 rms	501.0	0	6,012.0
12	.1 - 600	275 rms	1202.0	0	14,424.0
12	.1 - 600	275 rms	1150.0	2	12,200.0
12	.1 - 600	275 rms	500.5	2	5,643.0
12	.1 - 600	275 rms	500.0	0	6,000.0
12	.1 - 600	250 rms	500.5	0	6,006.0
12	.1 - 600	250 rms	502.5	0	6,030.0
12	.1 - 600	250 rms	500.0	0	6,000.0
					<hr/>
					292,336.6

Table VI

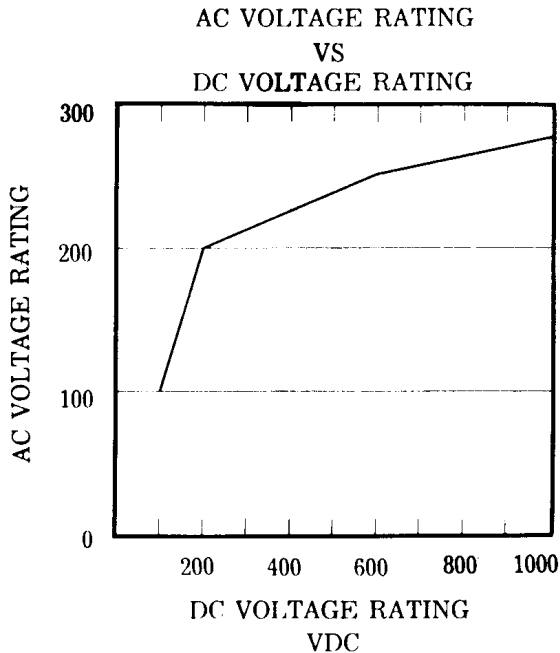


Figure 6

SUMMARY

Capacitors are frequently employed in circuits involving DC, AC and DC + AC voltage conditions in the design and application of electronic equipment. AC voltage conditions require special consideration due to the power the capacitor must dissipate and the possibility of corona producing conditions.

The purpose of this booklet is to give the conditions and effects of corona on Polyester-foil capacitors and a safe set of ratings for the various TRW Capacitor types. Data was presented to substantiate the ratings as well as indicate the expected life performance.

TRW CAPACITOR TYPES FOR WHICH AC RATINGS APPLY

TYPE	DC VOLTAGE	RATED TEMP	CONSTRUCTION
616-17	50-600	125° C	Hermetically Sealed
682-683	100-600	85° C	Hermetically Sealed
612-615	100-600	85° C	Hermetically Sealed
692-693 (CQ types)	30-1000	85° C	Hermetically Sealed
663UW	100-1000	85° C	Tape Wrapped
643 - CTM	50-200	125° C	Tape Wrapped
663F-663FR	100-1000	85° C	Tape Wrapped

For special conditions other than are mentioned in this booklet contact the Applications Engineering Department at TRW. They will be happy to assist you.